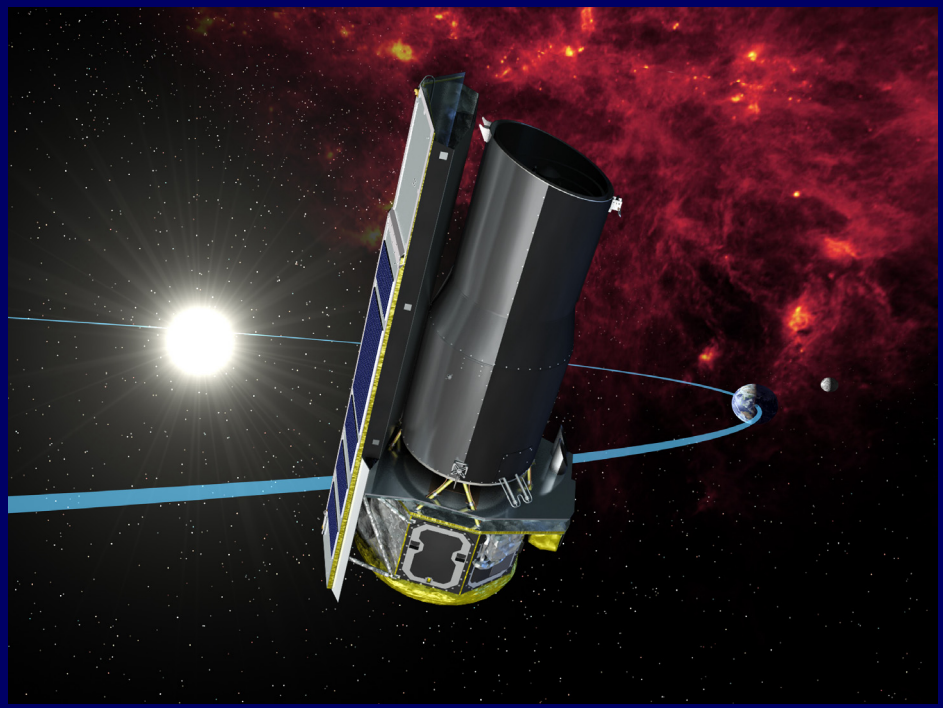

Star Formation Highlights from the Spitzer Space Telescope

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Outline

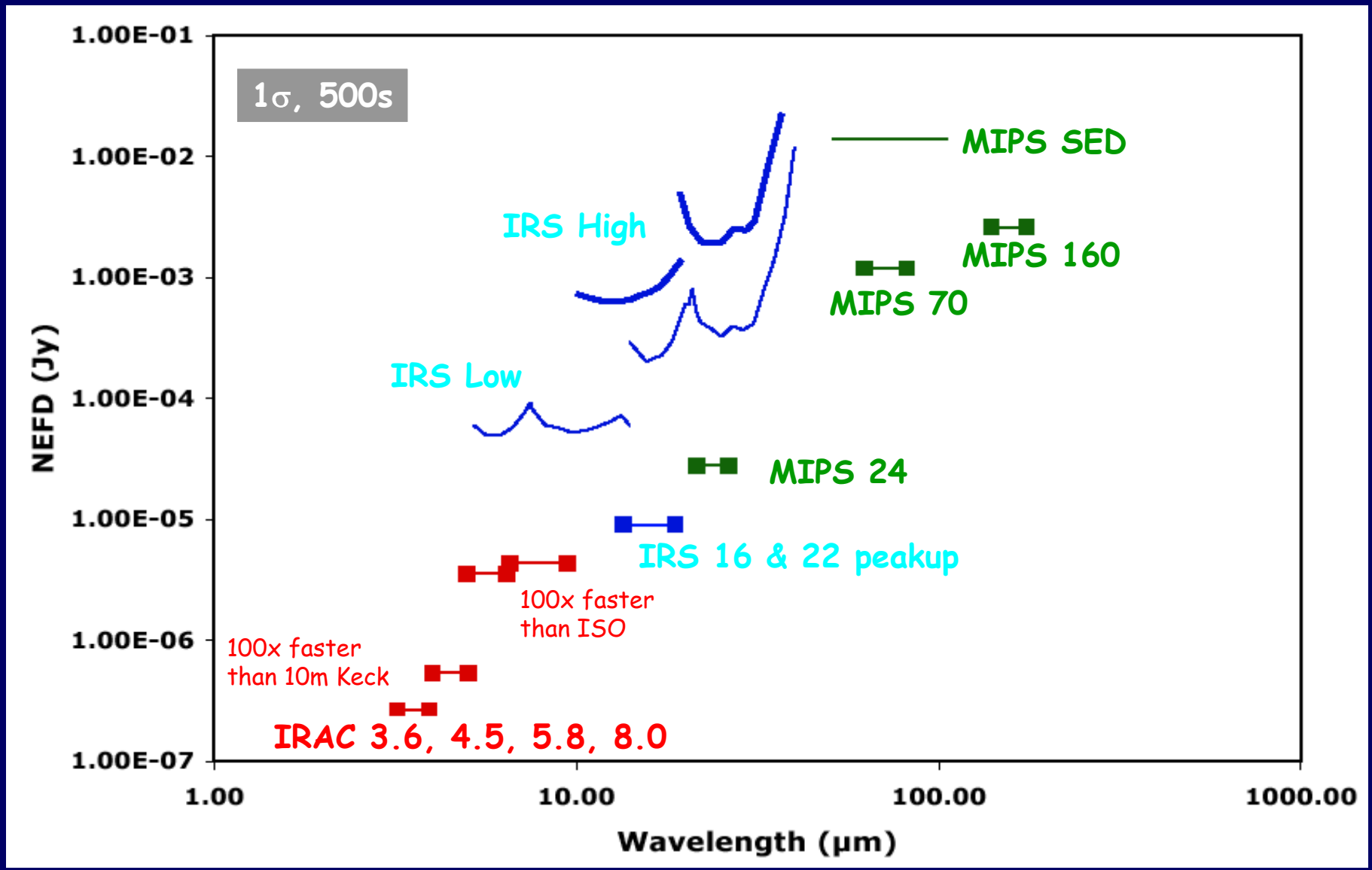
- Sampler of Star Formation Results from Spitzer
- Examples from Spitzer Young Disks Program
- Look beyond Spitzer

  – Articles are now available on SSC Web Site:
  http://ssc.spitzer.caltech.edu/pubs/journal2004.html

Key Spitzer Advancements

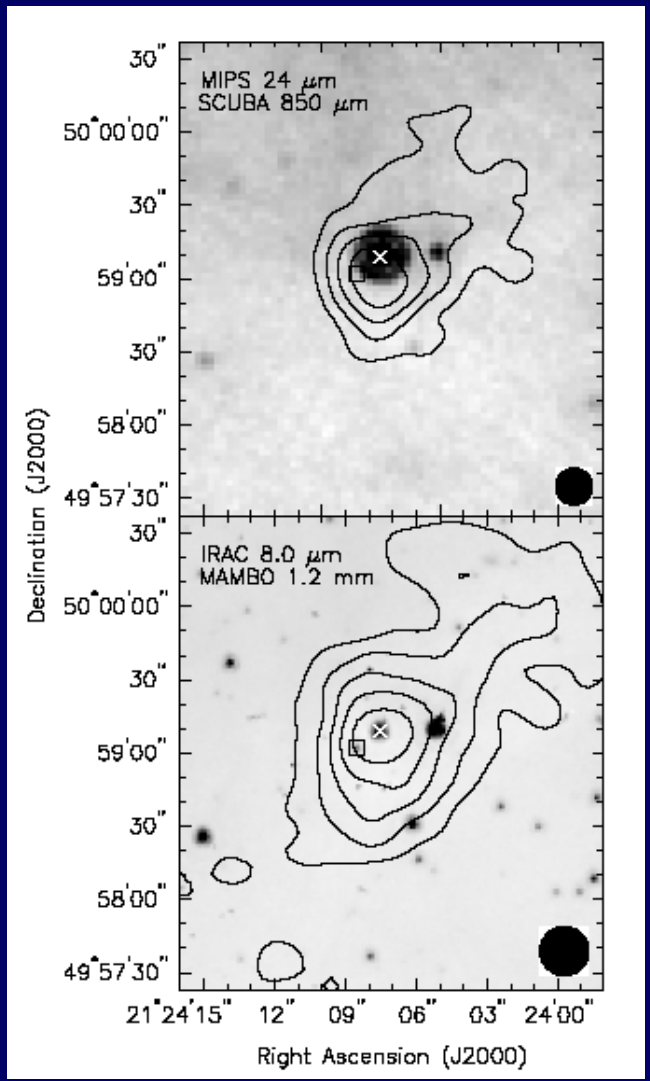
- Sensitivity
  - The lowest mass protostars are now within reach
- Large Detector Arrays
  - True imaging in the far infrared
  - Properly sampled PSF at long wavelengths
  - Efficient spectroscopic capability
- Efficient Mapping of Star Formation Regions
  - MIPS Scan map mode allows coverage of degree-scale areas
- Photometric Stability
  - Studies of even modest infrared excesses are enabled

Spitzer Sensitivity



Werner et al. (2004a)

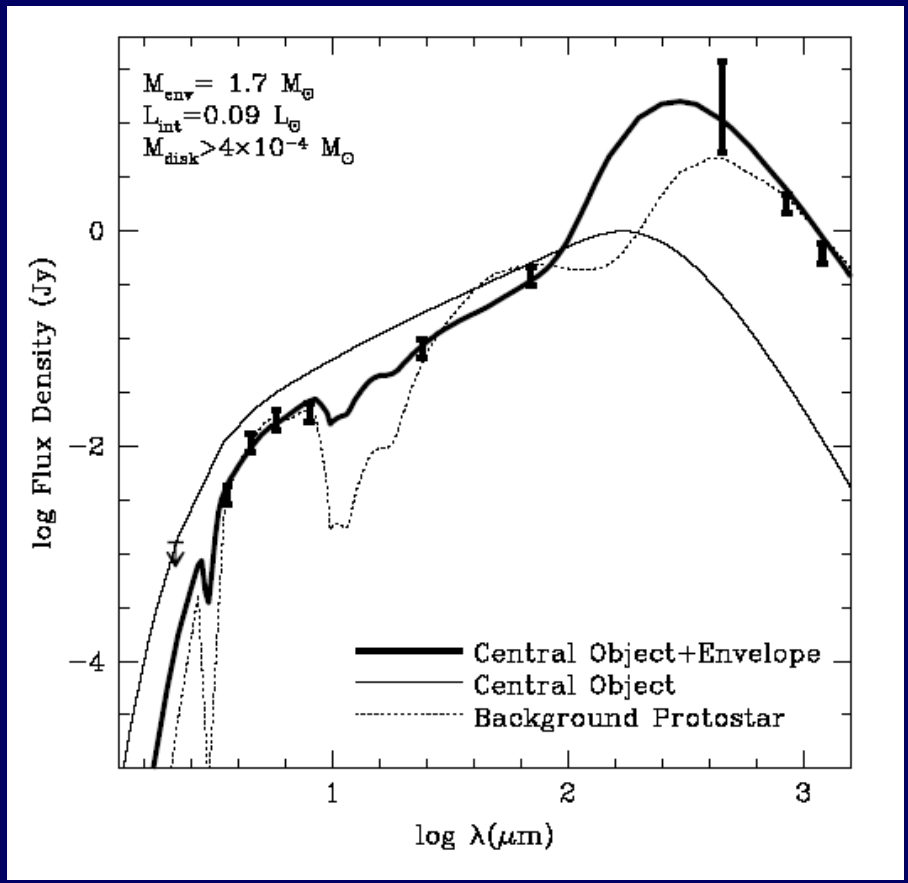
"Starless" Core with Protostar



- Cores to Disks Legacy Program
  - Neal Evans, PI.
- L 1014 Dark Cloud
  - Undetected by IRAS or ISO
  - Distance uncertain but it could be 200 pc based on lack of foreground stars

C. Young et al. (2004)

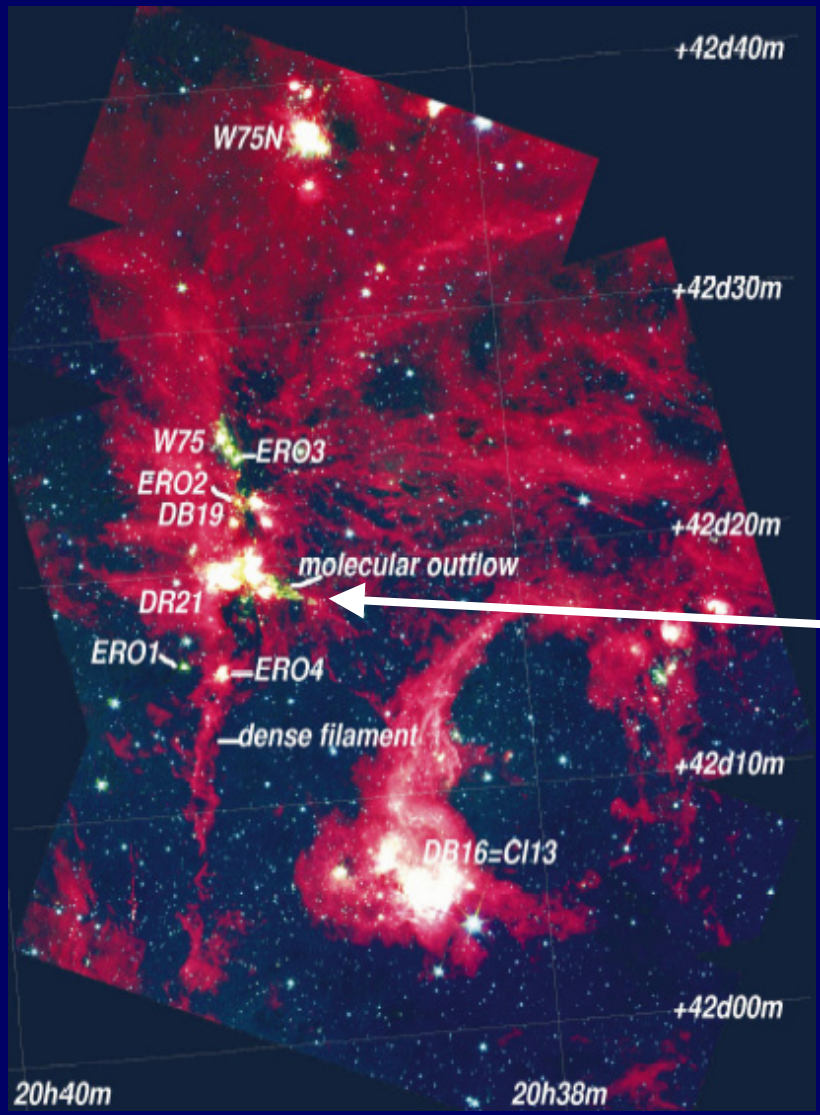
L 1014 – IRS SED



- Internal source may be substellar
- Internal source has "hot" + "disk" components
- Envelope has enough mass to form normal star
- Another "starless" core has an embedded source

C. Young et al. (2004)

DR 21 IRAC Observation



The large-scale IRAC view of the DR 21 region.

3.6 μm band (blue)
4.5 μm band (green)
8.0 μm band (red)

Molecular Outflows are prominent in the 4.5 μm band.

Marston et al. (2004)

NGC 7129 IRAC Observations

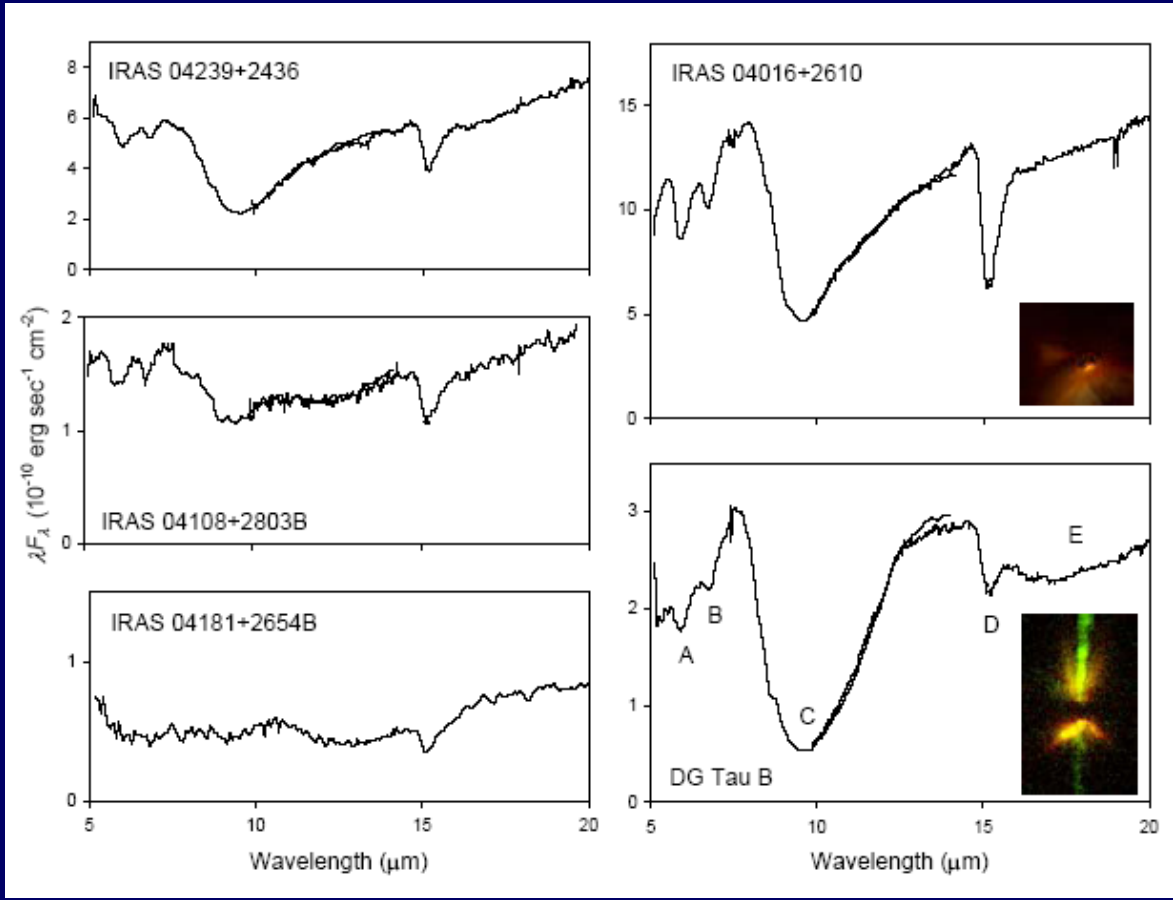
IRAC Image of NGC 7129 in Cepheus.

3.6 μm band (blue)
4.5 μm band (green)
8.0 μm band (red)

Molecular Outflows are prominent in the 4.5 μm band.

Megeath et al. (2004)

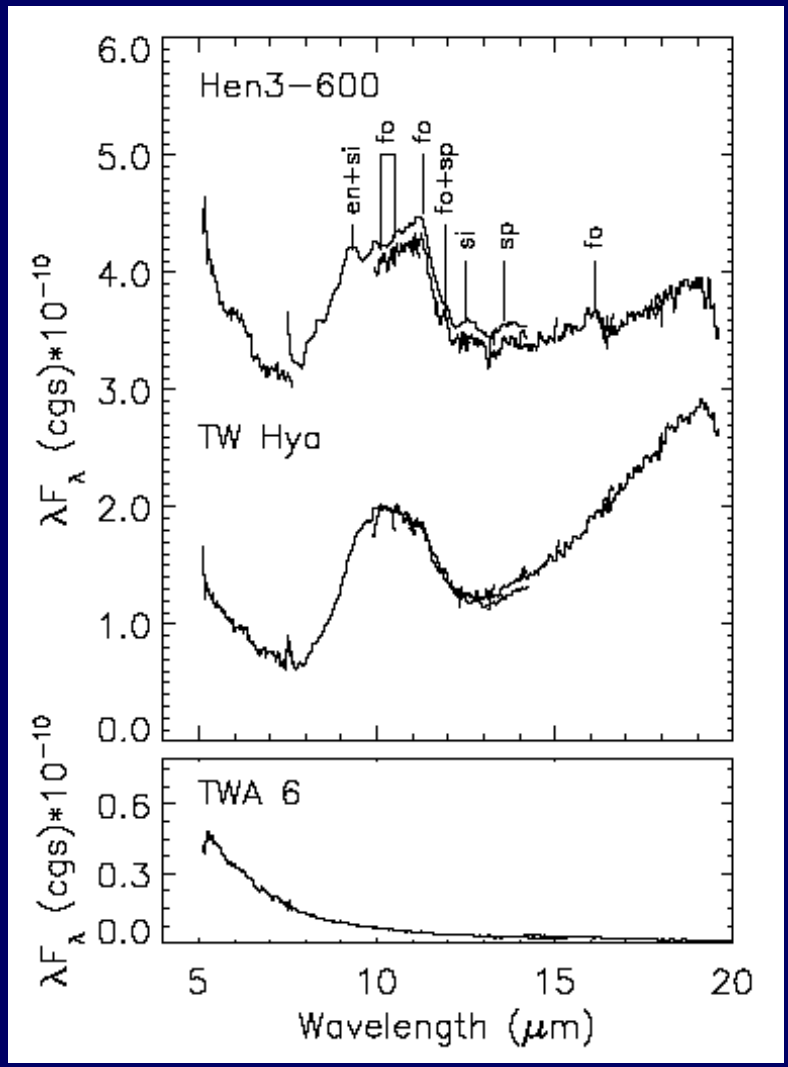
IRS Spectra of Class I Sources in Taurus



- A= H_2O
- B= CH_3OH
- C=Silicates
- D=CO_2
- E=Silicates

Watson et al (2004)

IRS Spectra of the TWA Members



- TW Hydra Association
  ~10 M yr Age
- 2 out of 7 stars have detectible excess emission
- Indication of silicate emission with highly processed minerals
  - Enstatite, Fosterite, Spinel

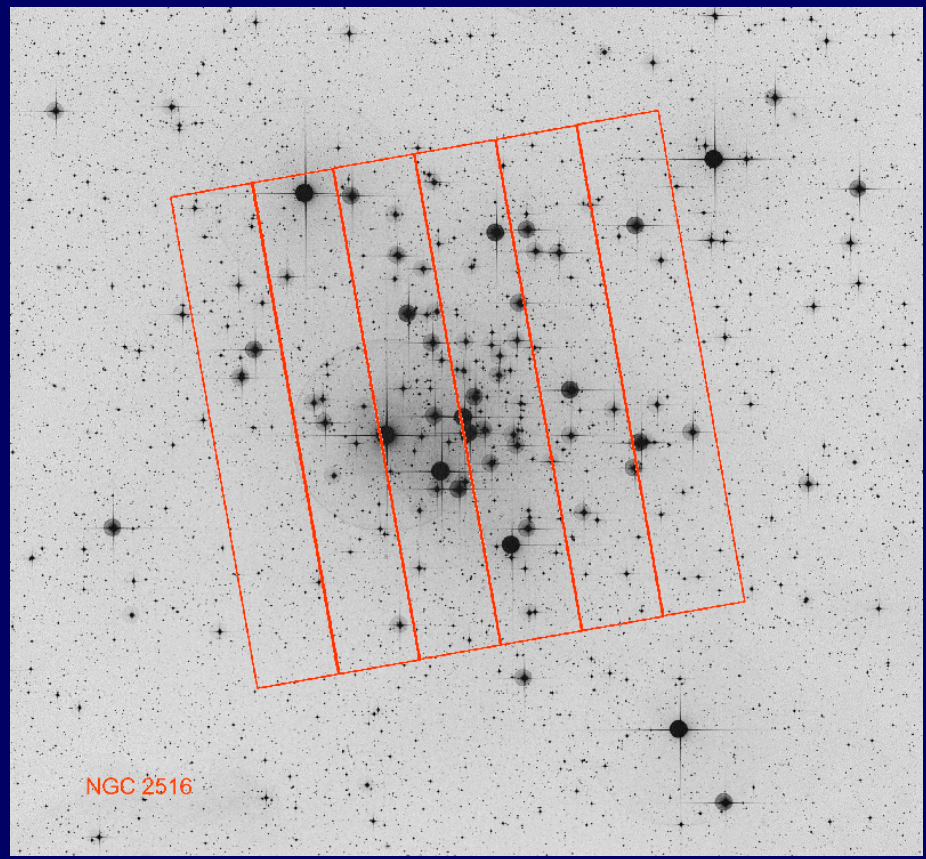
Uchida et al. (2004)

Open Questions About Disks

- When exactly does the thick disk dissipate?
  - Function of stellar mass?
  - Function of environment?
- Is the dissipation of the disk associated with the formation of large bodies in the stellar system?
  - Theory suggests that the accretion process for planetary bodies is very rapid.
- What are the details of the clearing process?
  - Where does the clearing start?

Spitzer Young Cluster Disk Survey

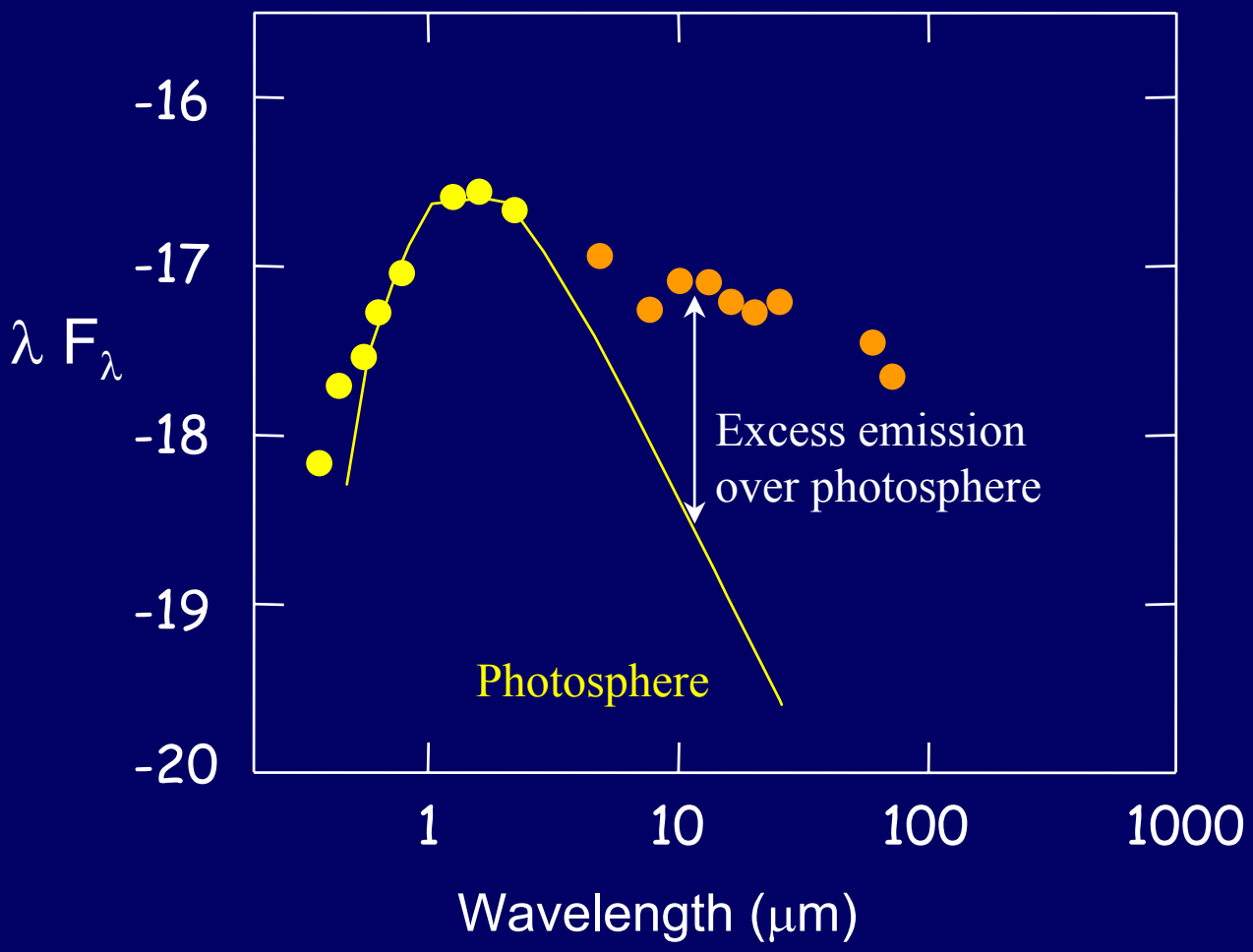
- Observing Strategy
  - 23 young fields <1 Myr to 150 Myr
  - Efficient collection of data for hundreds of stars in a coeval group
  - SIRTF Mid and Far Infrared sensitive to dust much farther from star than ground-based observations
  - Typical Area : 0.5° x 0.5 °
- MIPS Scan Maps
  - 24, 70, & 160 μm
- Matching IRAC Maps
  - 3.6, 4.5, 5.8, 8.0 μm



Disk Survey Collaborators

- Charlie Lada
- James Muzerolle
- John Stauffer
- George Rieke
- Paula Teixeira
- Elizabeth Lada
- Gus Muench
- Karl Gordon
- John Stansberry
- Tom Megeath
- Lori Allen
- Lee Hartmann
- Jane Morrison
- Chas Beichman
- Dean Hines
- Ken Wood
- Amy Mainzer
- Ian McLean
- Eric Persson
- & MIPS IDT

Spectral Energy Distributions Reveal Disk Structure



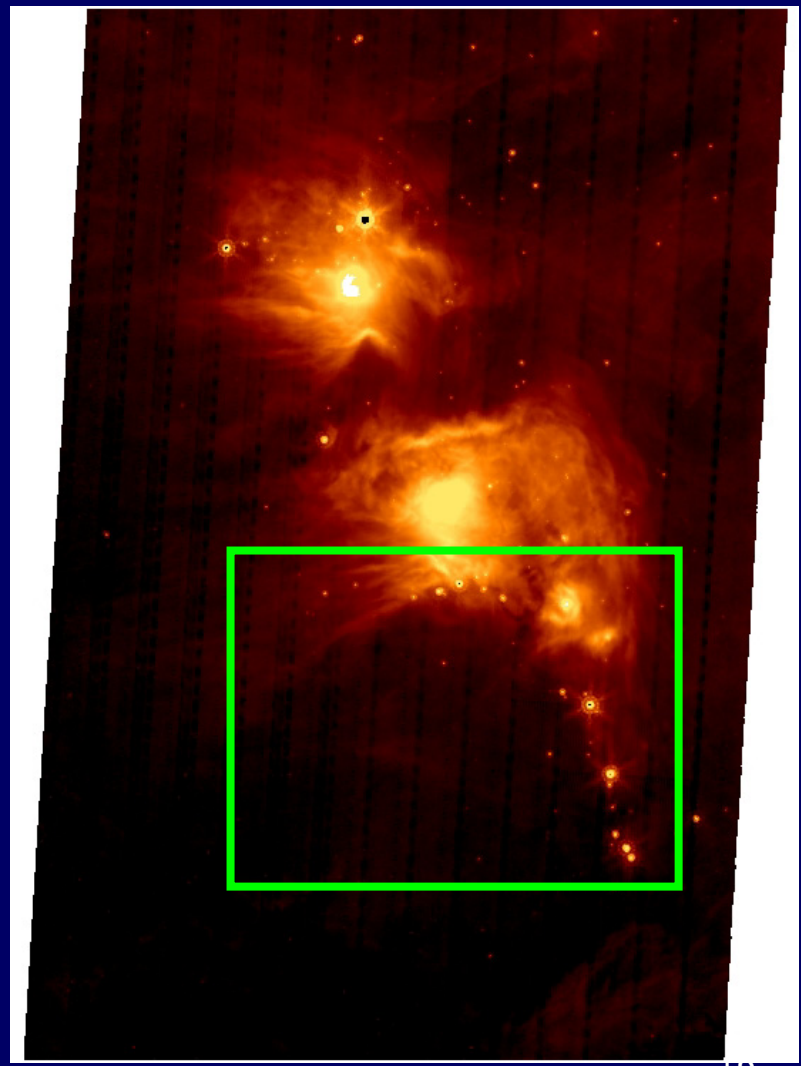
- Mid and Far-IR is sensitive to dust in the key planet-forming regions
- Far IR represents thermal dust emission.
- ISO and ground based observations indicate the disk clears after a few million years.
- Samples have been limited by sensitivity or confusion.

The Sample

	No O-stars	Single O-star	O-star Rich
< 3 Myr	ρ Oph, NGC 1333, NGC 2071, NGC 2068	Trapezium, σ Ori IC 1396	
3-10 Myr	IC 348, IC 5146, NGC 869, NGC 884	NGC 7160 NGC 2264, NGC 2362	NGC 6231, NGC 2244
10-40 Myr	NGC 2547, IC 2395	NGC 2451	
>40 Myr	NGC 2516, Pleiades	NGC 2391	

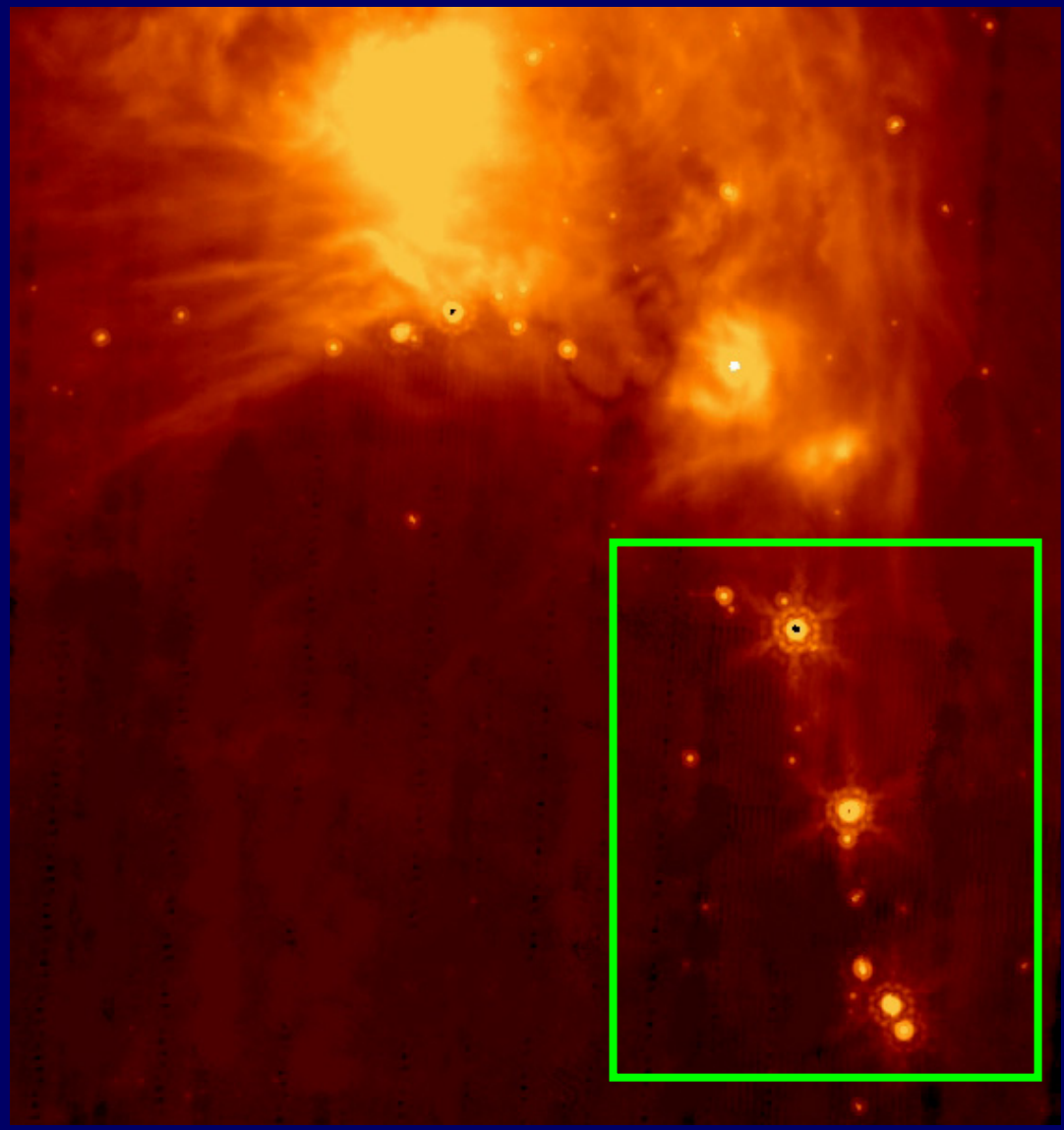
NGC 2068/ 2071

DSS



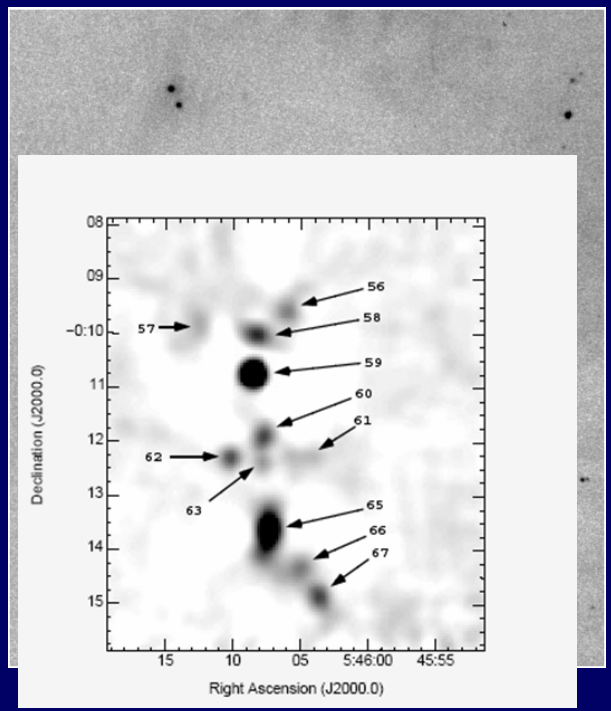
MIPS 24 μm

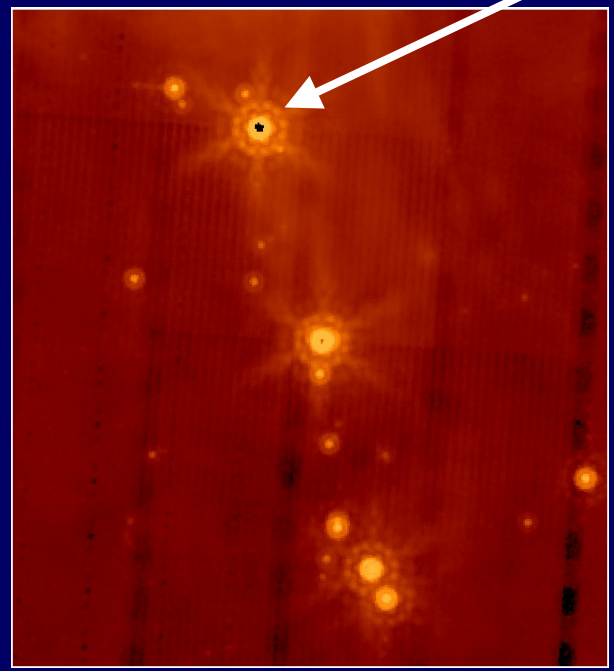
NGC 2068

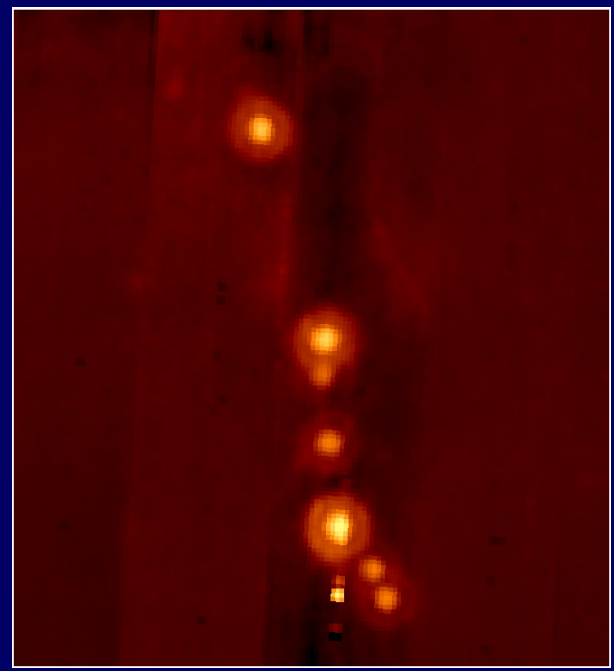


HH 24 Region

McNiel's Nebula







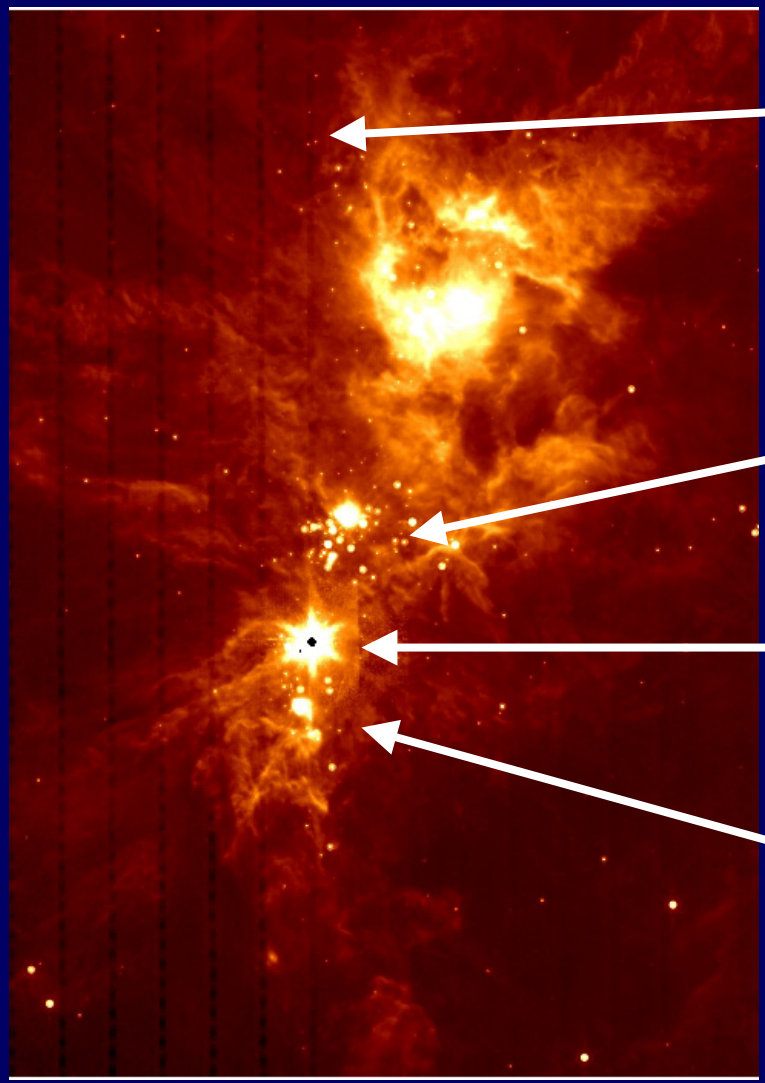
DSS

850 μm

MIPS 24 μm

MIPS 70 μm

NGC 2264



MIPS 24 μm Scan Map

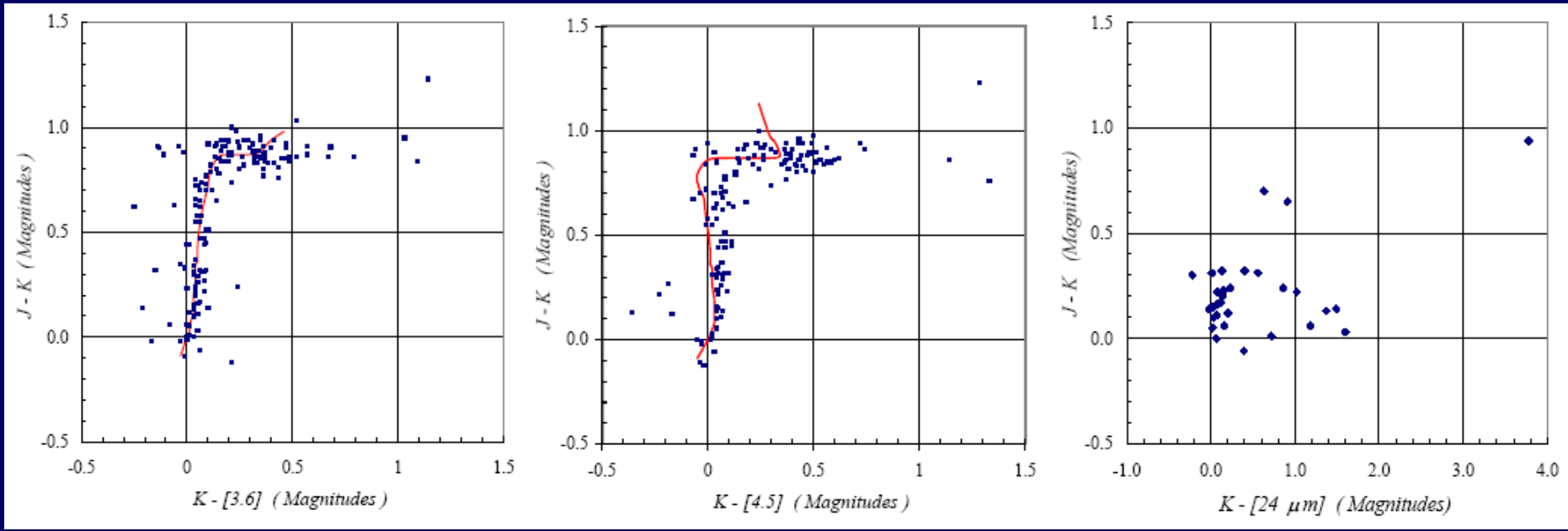
NGC 2547

3.6 μm

8 μm

NGC 2547 Composite

NGC 2547 Color-Color Plots



Results

- In the IRAC bands there is no evidence for excess infrared emission for any stars earlier than K5.
- For some of the M-stars, there may be some excess emission, but careful calibration of the intrinsic colors is still needed.
- At 24 μm, modest fraction of the stars show excess despite having photospheric colors at shorter wavelengths.

Summary

- Spitzer early results already demonstrate its power in star formation studies
  - Sensitivity to examine very low mass star formation
  - Wavelength coverage to address very early stages
  - Ability to get a global view of the process
- Future needs
  - Better Angular Resolution
  - Longer Wavelength Coverage
  - Velocity-Resolved Spectral Resolution in Sub-mm
    - Key Sub-mm lines of Carbon, Nitrogen, and Oxygen

Pleiades

SPITZER AND BEYOND INFINITY